Multidimensional evaluation of managed relocation

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Managed relocation (MR) has rapidly emerged as a potential intervention strategy in the toolbox of biodiversity management under climate change. Previous authors have suggested that MR (also referred to as assisted colonization, assisted migration, or assisted translocation) could be a last-alternative option after interrogating a linear decision tree. We argue that numerous interacting and value-laden considerations demand a more inclusive strategy for evaluating MR. The pace of modern climate change demands decision making with imperfect information, and tools that elucidate this uncertainty and integrate scientific information and social values are urgently needed. We present a heuristic tool that incorporates both ecological and social criteria in a multidimensional decision-making framework. For visualization purposes, we collapse these criteria into 4 classes that can be depicted in graphical 2-D space. This framework offers a pragmatic approach for summarizing key dimensions of MR: capturing uncertainty in the evaluation criteria, creating transparency in the evaluation process, and recognizing the inherent tradeoffs that different stakeholders bring to evaluation of MR and its alternatives.

assisted migration | climate change | conservation biology | conservation strategy | sustainability science

Managed relocation (MR) is an intervention technique aimed at reducing negative effects of climate change on defined biological units such as populations, species, or ecosystems. It involves the intentional movement of biological units from current areas of occupancy to locations where the probability of future persistence is predicted to be higher. The underlying motivation of MR is to reduce the threat of diminished ecosystem services or extinction from climate change. These threats interact with other facets of global change, including land-use change and biological invasions. MR has been used sparingly to date, but its importance as a conservation strategy is likely to grow as changes in climate become pronounced in the coming decades (1–3).

Several authors have evaluated the potential benefits and risks of MR, and its current prevalence (3–6), but little effort has been made to develop a robust strategy for evaluating the suite of benefits and risks associated with the strategy. Hoegh-Guldberg and colleagues (1) recently proposed a stepwise linear process to determine when it is appropriate to consider MR. Their framework identifies key information necessary to perform cost-benefit analyses. They identify several routes that do not lead to MR as the recommended strategy, and they envision MR as a last-ditch option should other conservation strategies be inadequate. In response to their analysis, several authors expressed additional concerns regarding specific risks associated with MR (7–9). Nevertheless, the decision-making process of whether or not MR should be performed has continued to receive little attention.

A tree approach to MR has several drawbacks that illustrate crucial aspects of the challenges presented by MR. First, complex conservation decisions such as MR are inherently poorly suited for resolution via decision-trees because a linear approach cannot accommodate the multiple dimensions of decision making (10). By allowing only 1 route to a particular decision, it is difficult to evaluate the relative merits of competing conservation options. Second, conservation decision-making tools are most valuable when they help to distinguish the social and cultural values used to judge acceptable risk from determinations of risk itself (where "risk" is the product of the probability of occurrence and potential consequence). A linear decision process does not depict choices between competing interests and needs. For example, deciding not to undertake MR could, in some cases, lead to extinction of some species to preserve other conservation values such as ecological integrity, ecosystem resilience, productivity, etc. Third, applied ecology, including MR, is fraught with uncertainty that cannot be adequately expressed by a decision tree with alternative pathways that imply sharp dichotomies (i.e., "yes" or "no"). Fourth, MR should probably not be defined, a priori, as the approach of last resort, but rather one of a portfolio of options.

Here, we propose a decision-making framework for MR that is multidimensional and informed by differences in social values. This framework can be used to characterize uncertainty and help establish priorities for MR among biological units and alternative conservation strategies. In many cases, alternate stakeholders will follow our framework and evaluate the relative measures differently (11). In so doing, the data and values used by each group are revealed.

Our multivariate framework can be conceptualized as a *N*-dimensional set of criteria that collectively address the costs and

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Table 1. Ecological and social considerations for evaluating individual cases of managed relocation (MR), wherein the goal is to prevent the loss of a species or population

Ecological criteria	Social criteria
Focal impact*	
Likelihood of outcome: Extinction Decline in geographic distribution Decline in abundance within geographic distribution Indirect effects of decline on community members and community composition	*Likelihood and consequence of outcome:* Cultural importance of the target and its community (e.g., is the target a flagship or iconic species? is the historic integrity of the community important?) Equity of the impact on particular groups of people Concerns about the harm to individual organisms subjected to MR Financial loss whether focal unit declines in abundance or goes extinct
Consequence of outcome: Uniqueness (phylogenetic, functional, etc.) Geographic distribution (common versus rare; small versus large range) The potential for reversibility (e.g., if no action were taken and the species went extinct in the wild, are there *ex situ* individuals available for population reestablishment)	
Collateral impact†	
Likelihood of outcome: Decline or extinction of native species in recipient region Decline or loss of ecological functions in recipient region	*Likelihood and consequence of outcome:* Cultural importance of the target and its community (e.g., is the target a flagship or iconic species? Is the historic integrity of the community important?) Equity of the impact on particular groups of people Concerns about the harm to individual organisms subjected to MR Financial loss whether focal unit declines in abundance or goes extinct
Consequence of outcome: Uniqueness of affected focal units Geographic distribution of affected focal units Effect on existing conservation efforts Degree to which effects are reversible (e.g., whether the focal unit could be easily controlled or managed once established in the recipient region)	
Feasibility‡	
Degree to which the target can be captured, propagated, transported, transplanted, monitored, or controlled Availability of appropriate sites for translocation Sustainability of MR in achieving conservation objectives (e.g., whether MR for a given focal unit would need to be performed iteratively to match changes in environmental conditions)	Economic cost Legal or regulatory obstacles (permits, etc.) that would hinder or restrict the capacity to conduct MR Regulations or laws that facilitate MR
Acceptability§	
N.A.	Willingness to accept potentially irreversible consequences (cultural, aesthetic, or economic) Willingness to support action Trust and acceptance of ecological information Aesthetic, cultural, and moral attitudes toward focal and collateral units Concern that a focal unit's protection will restrict land in the recipient region from being managed or developed Willingness to support new laws and policies that encourage or enable MR

This list is illustrative, not exhaustive, and will vary by case and stakeholder group. Additional criteria would be needed to consider MR if the goal was to replace a species complex or ecological function that had been lost from a system. In the case of focal and collateral impact, risk is measured by the likelihood of an outcome times the consequence of that outcome. N.A., not applicable.

*Impact on focal unit and its community from climate change and exacerbating effects of MR.

†Effect of focal unit in recipient region.

‡Constraints on or opportunities for MR.

§Societal willingness to pursue MR.

benefits of MR relative to other conservation strategies. Table 1 lists a subset of possible criteria. We distinguish criteria that are ecological from those that are determined by social values. Ecological criteria are subject to evaluation through available data or expert judgment, and evaluation of these criteria may change over time as new experiments and analyses are pursued. By contrast, the evaluation of social criteria changes as information moulds public perception and as cultural and social values shift over time. These 2 types of criteria interact; for example, social values inform which ecological studies are pursued. In many cases, MR may bring long-held conservation objectives into opposition, such as the maintenance of ecosystem

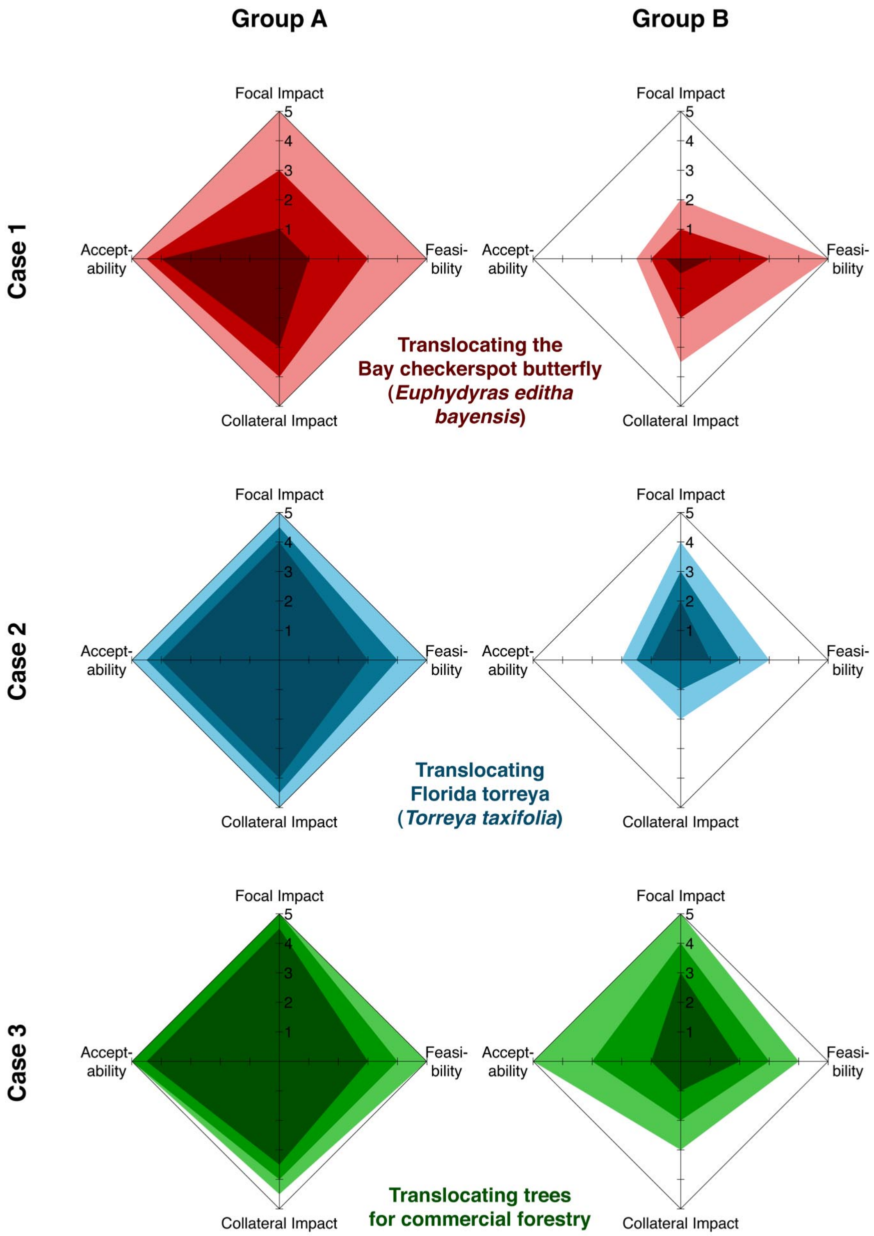

Fig. 1. A decision-making heuristic for managed relocation (MR). This heuristic is illustrated for 2 stereotyped stakeholders in each of 3 hypothetical cases (see *Methods*). Each case is evaluated along 4 axes: 1. Focal impact, 2. Collateral impact, 3. Feasibility, and 4. Acceptability (Table 1). These axes are scaled from 0–5, with low to high scores, respectively, except for the collateral impacts axis, which is scaled inversely (such that 5 is the lowest collateral impact). These axes create a 4-dimensional space but are illustrated in 2 dimensions. Consequently, polygons connecting the axes do not represent the actual volume of this space, but their shapes do convey a perspective about MR (see *Text*). Polygons with medium shading show mean scores; darker and lighter polygons show the lower and upper bounds, respectively, of uncertainty in these estimates. Case 1 illustrates how differing conservation groups could differentially evaluate MR for the Bay checkerspot butterfly (*Euphydryas editha* bayensis); this species is threatened by climate change and habitat destruction. Case 2 illustrates evaluations of MR for *Torreya taxifolia*, an endangered tree with a small endemic range in northern Florida that is threatened by disease and potentially by climate change. Case 3 is for MR of trees used in production forestry in Canada. All 3 cases show how different stakeholder groups could come to very different conclusions about MR, even with the same information.

integrity versus the importance of preserving individual species. Given the potential for strong disagreement, it becomes increasingly important that decisions on MR emerge from a transparent process that reveals the nature of the criteria invoked (12–15).

To illustrate this decision-support tool, we propose that criteria involved in the evaluation of MR can be categorized into 4 general classes (Table 1). These are 1) the impacts of conducting (or not conducting) MR on a given focal unit, 2) the impacts of MR activities on the recipient ecosystem, 3) the practical feasibility of conducting MR, and 4) the social acceptability of the action. The challenge of decision-making is then distilled to settling on a suite of attributes for grading in each class, ranking attributes within a class, and assigning a qualitative or quantitative score to each class. Together, the criteria-classes reveal the net benefits and risks associated with MR as perceived by the individual or group performing the evaluation exercise.

We illustrate a 4-class decision tool by displaying each class as a single axis in 2-D space (Fig. 1). Two axes capture risk, whereas 2 others specify implementation constraints on MR. Axis 1 (Focal impact) measures impact on the focal unit of interest and its community via indirect effects. These include impacts that occur without MR because of climate change and exacerbating effects of MR itself. Axis 2 (Collateral impact) measures the collateral effects of MR on nontarget organisms and ecosystems in the recipient region; this axis is scaled to decrease in magnitude with distance from the origin. Both of these axes capture 'risk,' the probability of an effect and the consequence of that effect (Table 1). Although probabilities of risk are amenable to transparent estimation and are theoretically knowable in many circumstances, limitations in time and resources impart bounds on the certainty of these estimates. Axis 3 (Feasibility) relates primarily to technical, logistical, or legal issues involving the practicality of implementation and the likelihood that MR (or any alternate conservation strategy) will achieve its stated objectives. Axis 4 (Acceptability), in contrast, captures the tolerance of MR activities, and its measurement resides largely in the domains of sociology and ethics (Table 1). Values for each of the first 3 axes include both biological (e.g., persistence versus extinction, invasion versus system integrity) and social value (e.g., economic and cultural importance of the focal unit) components, whereas Axis 4 is primarily driven by normative values that may be informed by the other axes (Table 1).

For each axis, teasing apart the relative effects of multiple criteria to generate a single value is nontrivial, but the exercise should be traceable, transparent, and repeatable. Scores on each axis also should be comparable among axes (i.e., on a standardized scale) and all values should be greater than 0. If the Focal impact axis were 0, for example, MR is unnecessary. Furthermore, one would expect all interventions to result in at least some collateral effect. Error bars on the values for each axis denote the level of uncertainty from incomplete information and/or variation among score assignments within a stakeholder group.

Given the configuration of the 4 axes in Fig. 1, a line can be drawn connecting the values and error bars on each axis. In general, polygons can be evaluated against each other. Diamond shapes indicate symmetry in rankings among the criteria. Triangles indicate asymmetrical scores in at least 1 axis, and narrow diamonds or vertical and horizontal stick shapes indicate asymmetrical scores in multiple axes. Larger shapes indicate overall higher scores in the evaluation criteria. Note that the shape formed by the connection of values and error bars on each axis is *not* the area of the actual parameter space because the heuristic comprises 4 dimensions depicted in 2 dimensions. Nonetheless, these 2-D shapes can help to inform decision making on MR and, as more cases are evaluated, should contribute to increasingly robust policies and strategies.

We illustrate the heuristic approach with 3 cases interpreted by 2 stakeholder groups that are crafted from available information (Fig. 1). These hypothetical stakeholders do not reflect actual individuals or groups but illustrate differing feasible outcomes in applying the tool. Our cases consider changes in species composition but the tool could be applied to biological units below the species level. Because cases differ along the 4 axes, our framework can be used to prioritize cases for MR consideration. The tool also can be used iteratively to compare alternative strategies for minimizing the biotic effects of climate change such as the creation of corridors or the application of management techniques in historical sites of occupancy.

The heuristic provides a multidimensional and transparent tool that incorporates both the ecological and social criteria that underlie controversial issues in conservation. Like other regulatory tools premised on the transparent disclosure of information, this heuristic could improve decision making by informing actors about the benefits and costs of alternative courses of action, catalyzing public participation and deliberation on an action's effects and alternatives, and increasing the public acceptability and legitimacy of decisions (16–21). We also anticipate that stakeholder groups using this tool are likely to find commonality in their views on MR that could serve as a starting point for policy discussion. A decision of nonaction based on intractable conservation disagreement may often result in a loss of biodiversity.

Materials and Methods

To illustrate the multidimension decision heuristic, we qualitatively evaluated 3 cases where assisted migration has or may be pursued, and we consider these cases from the point of view of 2, broadly stereotyped, stakeholders (Fig. 1). These 2 groups broadly fall into a proponent (group A) and opponent (group B) of MR, but real cases with multiple stakeholders will reveal less dichotomous perspectives. We have not surveyed these stakeholders or identified individuals that might fall into our hypothetical characterization. Instead, we built characterizations based on published data about each species, mission statements of groups concerned with each case, and discussion about species management for each case that can be found in the public domain. Detailed information about each case and the reasoning behind values selected are given in online methods, see SI.

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Supporting Information

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SI Text

Materials and Methods

Case 1: Translocating the Bay Checkerspot Butterfly,* Euphydyras editha *bayensis. This specialist butterfly lives in grasslands on serpentine soils in the San Francisco Bay area of California. It is federally listed as threatened, and habitat loss from human development and invasive grasses that outcompete its native food plants have diminished and isolated its populations. The butterfly and its host plants were probably once widespread (1), and recent studies suggest that remaining patches are susceptible to extinction (2). To persist under climate change, *E. editha* bayensis needs larger habitats with greater connectivity, a difficult prospect in an urban area. To enable species persistence, the butterfly could be relocated to areas free of urbanization that are likely to have suitable climatic conditions in the future.

The Bay checkerspot, however, is just 1 subspecies of a widely distributed species that occurs throughout western North America. All populations of *E. editha* feed on plants in the families Plantaginaceae or Orobanchaceae, but individual populations specialize on different species (3). A common feature of *E. editha* populations is a sensitive phenological relationship between larval development and host plant senescence, a relationship strongly affected by climate (4, 5). The Bay checkerspot feeds on *Plantago erecta*, *Castilleja exserta*, and *C. densiflora*. These plants have broad distributions in California, but might be introduced or increased where butterfly populations were translocated. In areas off serpentine soil where competition with nonnative is most intensive, large-scale restoration and habitat creation may be necessary to facilitate host plant populations. In this case, we envision an introduction to northern California. Translocations beyond California may require the introduction of nonnative host plants unless the Bay checkerspot could be shown to consume native hosts.

Evaluation of Case 1 by Stakeholder A, ''Advocate for Bay Checkerspot Preservation.'' *Feasibility Score is 3 (± 2)*: It is uncertain whether this species can be moved successfully. Attempts at within-range introduction have had mixed results, but a successful captive breeding program does exist for *E. editha taylorii*, another threatened subspecies (http://www.oregonzoo.org/Conservation/silverspot.htm). The Bay checkerspot's host plant requirements may necessitate considerable habitat modification and enhancements, but if the introduction occurs in California, those host plants species are native and serpentine grasslands are fairly common in northern California. These considerations lead to a high feasibility score with large variance. *Acceptability Score is 4.5 (± 0.5)*: As a federally-listed species, there is a mandate for conservation of this species. It also is a flagship of the native California grassland, providing historic and aesthetic motivations for preservation. This desire for protection leads to a high acceptability score with small variance. *Focal Impact is 3 (± 2)*: Although recent data suggest that populations may be vulnerable to extinction (1), this outcome is not certain for all populations, and conservation of existing populations may be possible by encouraging the abundance of long-lasting hosts, [e.g., *Castilleja* spp (6)] or by restoring or creating serpentine grassland habitats. Thus, the focal impact score is moderate with a large variance. *Collateral Impact is 4 (± 1)*: The butterfly seems unlikely to competitively displace native species in the host region as it rarely defoliates host plants in the Bay Area [but see (7)]. Further, the butterfly may help to provide additional pollination services to native plants where it is introduced (8). These assumptions lead to a high score (low collateral damage) with some variance.

Evaluation of Case 1 by Stakeholder B, ''Conservationist in Introduction Region.'' *Feasibility Score is 3 (± 2)*: Same as above. *Acceptability Score is 1 (± 0.5)*: The checkerspot is unlikely to provide ecosystem functions that are not currently represented in the introduced region. Further, facilitating host plants of the Bay checkerspot could disturb native *E. editha* or other butterflies that feed on competing plant species. Thus, the acceptability score low with low variance. *Focal Impact is 1 (± 1)*: This species may not go extinct in its natural range. Further, even if the butterfly species were lost, it is unclear (given its low abundance already) whether it would have any significant impacts on the functioning of its own native system. As a subspecies, little phylogenetic distinctiveness would be lost. Conservationists outside the Bay Area acknowledge that this species is an important member of its community in a cultural, social, and legal sense, but they value these qualities less than Bay Area residents. Thus, focal impact is given a low score with moderate variance. *Collateral Impact is 2 (± 1.5)*: This species is unlikely to have large effects in its introduced range, but it might disrupt the functioning of the existing native system, potentially putting native species at risk. The habitat creation or facilitation needed for introduction may replace or compete with other valued species. Some of these species may be the host plants of conservation targets in the recipient region (e.g., Oregon, Myrtle's, and Behren's silverspot butterflies). Introduced *E. editha* bayensis also could compete with, replace, or hybridize with native *E. editha*. This could reduce the diversity of local fauna or pollute the local gene pool. Thus, the score for 1-collateral damage is low, but the possibility of little damage leads to a high variance.

Case 2: Translocating* Torreya taxifolia *to the Southern Appalachians. *Torreya taxifolia* (Cephalotaxaceae) is a dioecious coniferous tree that is endemic to the bluffs that extend 5–10 km eastward from the Apalachicola River for approximately 35 km in northern Florida, extending less than a kilometer into Georgia (9–11). During the late 1950s and early 1960s, all adult trees throughout its range were killed as a consequence of a pathogen outbreak (12). The current population is likely not >1,500 individuals (13), likely seeds and seedlings that were viable at the time of the decline (11). During the past 40 years, there has been a single tree that has been observed to have matured into a seed bearing adult. It produced 2 seeds. This individual is now dead, and the seeds produced are presumed dead as well. The agent of the decline is unknown but is thought to be a fungal pathogen (14–15). The current rate of decline is slow. Estimates of growth and mortality data suggest that it will be at least a century before the population goes extinct in the wild (3). Cuttings from ≈150 trees are currently grown in botanic gardens.

More recently, 2 efforts have begun for the conservation of this species. *Torreya taxifolia* has been planted in North Carolina in an attempt to establish populations in that region (http://www.torreyaguardians.org/). This effort was done as an indirect response to climate change. The species is in declining in its native range with no sign of recovery. Proponents felt that this species 'belongs' in the region where they relocated it. They also feel that this intervention is the best chance for the species to survive, given its condition in its native range.

Evaluation of Case 2 by Stakeholder A, ''Advocate for a Broad Distribution of* Torreya taxifolia*.'' *Feasibility score is 4 (± 1)*: Seeds are moderately easy to germinate; plant material in the form of cuttings are legally available through several botanical gardens in possession of numerous genotypes of known origin. Cuttings, however, take many years to reestablish apical dominance, so the process is slow. With a small number of mature female trees at Biltmore Gardens (Asheville, NC), the most available seed represents a very narrow subset of the genetic variability of the species. Although this is a federally listed species, it is possible to plant legally obtained plant material on private lands without seeking state or federal approval or permits. *Acceptability score is 4.5 (± 0.5)*: The species is generally sparse and does not tend to form monospecific stands. The likelihood of this species becoming weedy is low. *Focal Impact score is 4.5 (± 0.5)*: There is no supportive evidence that we can conserve the species in its recent historical range. *Torreya taxifolia* represents 1 of 2 North American species in the genus and 1 of 5 North American Representatives in its family; 1 of 7 species in its genus and 16 species in its family worldwide (17). Loss of this species significantly erodes biodiversity. *Collateral impact score is 4.5 (± 0.5)*: This species is slow growing, produces few seed and is of relatively small stature as a mature tree. Being dioecious and producing relatively few seeds, this species would be relatively easy to control. Related taxa tend to be found either in localized patches or as subdominants in mixed forests. It appears unlikely to dominate and displace other Appalachian forest species [none of the 10 species in the family are known to be invasive when planted outside their range (18)].

Evaluation of Case 2 by Stakeholder B, ''Advocate for Local Conservation of **Torreya taxifolia.''** *Feasibility score is 2 (± 1)*: *Torreya taxifolia* is a federally listed species. Thus, even though it may be legally possible to translocate the species, actions should be conducted under the auspices of the relevant federal agencies. Cooperation with federal agencies appears unlikely. The limited number of parental genotypes available for seed would force reintroduction to drive the species through a genetic bottleneck. *Acceptability score is 1.5 (± 0.5)*: The introduction of this species will erode the ecological integrity of a very diverse forest community type that is, itself, threatened by climate change. There is currently strong public support for conservation of local forests based on the argument that this region protects essential and irreplaceable biodiversity; adding a nonnative species will erode this support by arguing, effectively, that the local biodiversity might also be conserved somewhere else through managed relocations. *Focal Impact score is 2 (± 1)*: While recognizing that the species is an important representative of a small lineage, the species is currently being grown in botanical gardens. It would be a simple step to plant the species as yard trees to help preserve this lineage. The persistence of this species does not depend on finding new wild habitats. Further, there is not sufficient evidence to suggest that restoration of the species within its current range is not feasible. Adequate local restoration must be tried and shown to fail before this species should be moved. Climate change may pose an issue for this species, but we know that introduced pathogens were the proximate cause of the decline. We need to wait until we have documented proof that a local solution is not possible. *Collateral impact score is 1 (± 1)*: Introducing this species to southern Appalachian mixed forests is unacceptable because it may disrupt critical ecosystem attributes of local forests and displace species. Conifers produce more acidic litter than hardwoods, an introduction of this sort, if successful, is likely to alter local soil chemistry and trigger other less predictable ecosystem changes. We simply cannot predict the impact of this introduction.

Case 3: Translocating Trees for Commercial Forestry. A mixture of regulations and guidelines varying by province encourages the plantation of locally adapted seedlings on production forest land in Canada (19). Until recently, restrictions on seed transfer have emphasized local climatic adaptation of tree stock in a static setting (e.g., fixed boundary seed zones), but there is increasing discussion about amending seed transfer guidelines to accommodate climate change (18–21). The primary impulse for considering the transfer of genotypes or species into novel areas predicted to be suitable by climate models is economic, but conservation and carbon sequestration are also relevant considerations (20, 22). Any prospective benefits of relaxing seed transfer restrictions to accommodate climate change must be understood in the context of ongoing debates about the impact of Canadian forestry on biodiversity (23, 25).

Evaluation of Case 3 by Stakeholder A, ''An advocate for Production Forestry.'' *Feasibility score is 4 (± 1)*: There is a well-established seed transfer policy and infrastructure framework that could be modified to allow the implementation of climate-based seed transfer (22). Reports that examine such changes indicate that the major feasibility challenge is uncertainty about the degree and direction of future climate change and the nature of local adaptation in trees, that is, whether MR would improve forest production (19, 22, 26) rather than infrastructural or economic constraints. *Acceptability Score is 5 (± 0.5)*: Reports from groups studying this issue argue that increasing maladaptation of tree species to their environment under climate change risks reducing forest productivity and forest health including the resilience of forests to pests and disease (20, 22). Furthermore, climate-based seed transfer may not be perceived as categorically different from current practices (19). *Focal Impact is 5 (± 0.5)*: If the focal unit under consideration is the forest ecosystem, foresters seem to agree that transferring species and genotypes better adapted to future climates will improve productivity and resilience (20, 22). *Collateral Impact is 4 (± 0.5)*: There is little discussion of potential negative impacts of climate-based seed transfer on nearby nonproduction forests in published reports and the benefits envisioned for forest health in focal sites might be expected to provide some regional ecosystem stability (22).

Evaluation of Case 3 by Stakeholder B, ''Natural Heritage Conservationist.'' In contrast to the recent increase in reports by forest managers specifically addressing this MR scenario, we could find no published analysis of climate-driven seed transfer from environmental conservation groups. We note that revisions to provincial management plans will allow input from nongovernmental environmental advocates and that these advocates may agree with production foresters on the need and desirability of MR. However, past conflicts on Canadian forest policy suggest that differing perceptions about the role of production forests (27) might result in differences of opinion about the desirability of this policy shift. *Feasibility Score is 3 (± 1)*: Consistent with the views of production foresters (above), environmental advocates likely do not see the main obstacles to feasibility as infrastructural. However, some forest conservation groups in Canada have been skeptical about the role that production forests will play in mitigating the impacts of climate change. In particular, environmental groups have argued that management for timber extraction leads to inefficient carbon storage in forests (24). Under such reasoning, productivity gains associated with MR might ultimately contribute little to carbon sequestration. These groups have also argued that production forests have a low capacity to facilitate the adjustment of biodiversity to warmer climates relative to extensive natural forests (24). *Acceptability Score is 3 (± 2)*: Like production foresters, environmental advocates are searching for ways to ameliorate projected increases in forest stressors and migration lags under climate change (25). Revised seed transfer policies on production land might be considered coherent with those shared goals. However, the prospect of widespread transfer of nonindigenous genotypes might raise concern in the conservation community about the consequences of manipulating local genetic structure. *Focal Impact is 4 (± 1)*: Because environmental advocates see similar threats from climate change to ecosystem stability as production foresters (24, 25), they may perceive the potential ecosystem impacts on focal forests similarly. Some environmental advocates, however, are less confident that intensive management is effective at addressing such problems, and they may discount impact accordingly. *Collateral Impact is 2 (± 1)*: Some groups might fear negative impacts on natural forests from species and genotypes escaping from production lands. This action might also risk a loss of sense of place and an alienation of local people from their environment.

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